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EFFECTS OF GRAZING UPON WESTERN YELLOW-PINE REPRODUCTION IN THE NATIONAL FORESTS OF ARIZONA AND NEW MEXICO.

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IMPORTANCE OF PROTECTING PINE REPRODUCTION.

The best summer forage in Arizona and New Mexico is found among the open stands of yellow pine, mainly at elevations above 6,000 feet, and covering more than 8,800,000 acres, or 6 per cent of the total area of the two States. (See map, fig. 1.) Every economic consideration requires that this forage, one of the region's most important resources, should be converted into meat. At the same time, it is important that this should be done with the least possible injury to the yellow pine, which is by far the most important timber of the Southwest. In many places the tree is not reproducing satisfactorily, hence it is very necessary to protect the young growth (which in any event has to contend with severe winters, dry springs, and parasites and insects) from damage by stock.

The problem is especially important in the National Forests, which are created primarily to conserve the timber supply and to protect the vegetative cover on the watersheds. In the Forests is the bulk of the yellow pine in Arizona and New Mexico, and on the National Forest range are grazed approximately 30 per cent of all the range stock in the two States. Stock use the Forest range mainly during the summer, from April to November.

This bulletin presents the results of a study to determine the character and extent of the damage to young growth of western yellow pine in the Southwest from the grazing of live stock, and to find out the best means of keeping such damage at a minimum while permitting proper utilization of the range.

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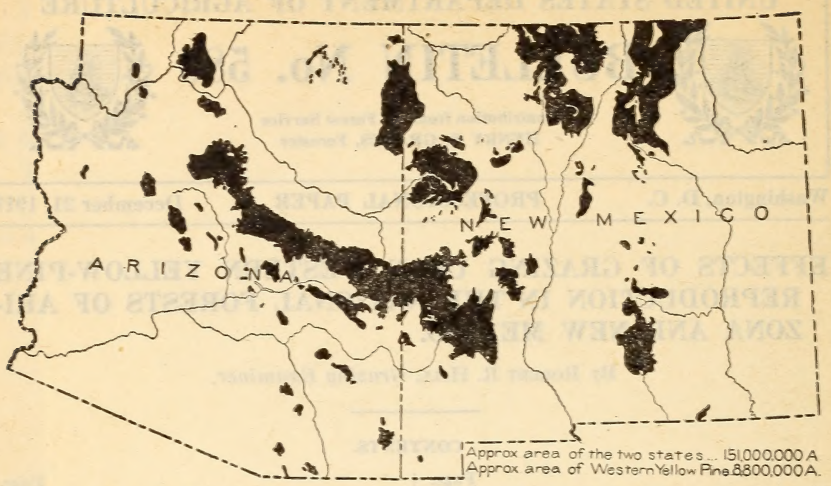

FIG. 1.—Yellow pine in Arizona and New Mexico.

SCOPE AND METHOD OF STUDY.

An intensive study was made on the Coconino National Forest, in the north-central portion of Arizona, where grazing and timber conditions are typical of the forests of the Southwest, and where the problem of securing satisfactory timber reproduction is often serious. This was supplemented by general observations, covering a period of two years, on other Forests in Arizona and New Mexico. The observations were confined chiefly to the yellow-pine type, but for purposes of comparison some observations were made in the Douglas fir and piñon-juniper types.

Early in the season of 1910 a preliminary reconnaissance was made on the Coconino Forest. This was followed during that year by a detailed study, in which observations were made upon 150 plots. Further observations were made in 1912 on additional plots. Altogether 250 plots were observed within a radius of 25 miles of Flagstaff, in the heart of the Forest.

The plots were located so as to include the following range conditions:

(1) Areas embracing all conditions of range normally grazed by different classes of stock.

(2) Areas embracing all conditions of range overgrazed by different classes of stock.

(3) Areas supporting a good stand of forage normally grazed by all classes of stock.

(4) Areas supporting a poor stand of forage normally grazed by all classes of stock.

(5) Areas supporting chiefly bunch grasses, grazed by different classes of stock.

(6) Areas where cattle congregate.

(7) Areas where sheep congregate, *i. e.*, along driveways and on bed grounds.

The plots were selected where representative rather than abnormal injury was in evidence. In order to secure maximum results from a limited amount of work, the plots were located where the stand of seedlings was fair to good. They were laid out in quadrangles, varying in size from 10 feet by 30 feet to 30 feet by 90 feet, depending upon the size and density of reproduction.

All seedlings and saplings of a size subject to grazing were counted. An attempt was made at first to classify the damage according to such divisions as "leader destroyed," "needles removed," etc., but it was found that this did not give an accurate idea of the amount of damage actually done without a great deal of qualification. For this reason, it was decided to base the classification upon the permanent effect upon the development of the tree which, in the opinion of the observer, the damage would cause. Plants on which the leader, side shoots, and needles had been so severely grazed that the growth of the plant would be seriously interfered with for at least a number of years, were classed as "injured." Where the damage was not so severe, but if continued would seriously interfere with the development of the tree, the plants were classed as "severely browsed." Where the damage was severe enough to interfere to a very considerable extent with the development of the tree for a period of from one to three years, but not so severe as to affect its ultimate development even though the usual amount of damage were to continue, the tree was classed as "moderately browsed." Where the damage was so slight that its effect would not be noticeable after the current year, the plant was classed as "lightly browsed."

The trees were classified according to height by ocular estimate as follows:

Below 6 inches	Seedlings.
6 inches to 1.5 feet	1-foot class.
1.6 feet to 2.5 feet	2-foot class.
2.6 feet to 3.5 feet	3-foot class.
3.6 feet to 4.5 feet	4-foot class.
4.6 feet to 5.5 feet	5-foot class.
5.6 feet to as high as were subject to grazing	Above 5-foot class.

Four examinations were made in 1912 and in 1913 at intervals during the grazing season to show the amount of seasonal damage. The first examination was made during May, to record the amount of damage at the beginning of the grazing period; the second examination was made early in July, to indicate the amount of damage that occurred during the spring dry period; the third early in September, to determine the amount of damage done during the best growing period; and the fourth early in November, at the close of the grazing season, to record the damage done during the fall drying

period and also the total amount of damage during the entire grazing season. An examination was made also at the close of the 1914 grazing season. Thus data on seasonal damage are available for two years, and data on total annual damage for three years.

A supplemental study was undertaken in 1912 to determine the effects of protection from grazing upon the establishment, growth, and recovery of yellow-pine reproduction, and incidentally of forage plants. In each of five areas subject to close grazing and representative of soil classes and forage types in the western yellow-pine belt, 2-acre plots were fenced so as to exclude all grazing. Check plots, established in the immediate vicinity of the fenced plots, were left to the usual amount of grazing. The height and spread of crown of the young trees within the plots were measured, and the location of each tree was recorded. In addition, the severity and probable date of past grazing injuries were noted. These data were secured in 1912, 1913, and 1914. It is planned to repeat the examination every third year until a period of 10 years has elapsed, or until conclusive results are obtained.

EXTENT OF DAMAGE TO WESTERN YELLOW-PINE REPRODUCTION FROM GRAZING.

AVERAGE ANNUAL DAMAGE.

The average annual damage to western yellow-pine reproduction due to grazing under existing practice is shown in Table I. The figures are those obtained during the final examinations at the close of the grazing seasons of 1912, 1913, and 1914. It will be seen that 42 per cent of the total number of trees observed are damaged to some extent annually.

TABLE I.—*Annual damage to western yellow-pine reproduction from grazing.*

Year.	Number of trees observed.	Injured.		Browsed.					
				Severely.		Moderately.		Lightly.	
		Number.	Per cent of total.	Number.	Per cent of total.	Number.	Per cent of total.	Number.	Per cent of total.
1912	8,945	853	9.5	1,035	11.6	2,240	25	896	10
1913	8,945	492	5.5	871	9.7	1,301	14.5	915	10.2
1914	8,945	448	5.0	589	6.6	698	7.8	382	4.3
Average annual	8,945	598	6.7	832	9.3	1,413	15.8	731	8.2

TABLE I.—*Annual damage to western yellow-pine reproduction, etc.*—Continued.

Year.	Number of trees observed.	Rubbed.						Dead.	
		Severely.		Moderately.		Lightly.			
		Number.	Per cent of total.	Number.	Per cent of total.	Number.	Per cent of total.	Number.	Per cent of total.
1912	8,945	10	0.1	5	0.1	1	0.0	50	0.6
1913	8,945	54	.6	46	.5	20	.3	94	1.0
1914	8,945	125	1.4	36	.4	1	.0	105	1.2
Average annual...	8,945	63	.7	29	.3	7	.1	83	.9

In order to arrive at the number of trees damaged to such an extent as seriously to retard their growth, it is necessary, under the plan of classification, to include only the injured, the severely browsed, and the severely rubbed trees. Estimated on this basis, 1,493 trees, or 16.7 per cent of the total number examined, are subject to severe damage by grazing. It is this class of damage, rather than the total damage, that is of serious importance.

It is believed that the figures given represent fairly the actual damage over approximately one-half of the yellow-pine type on the Coconino Forest and that similar damage will occur elsewhere under like conditions. Conditions under which the damage is greater or less than the average are pointed out in the later discussions.

DAMAGE BY HEIGHT CLASSES.

The extent of damage done to trees of different sizes is shown in Table II.

The conclusions drawn from this table are that damage is most severe in the seedling class and gradually shades off as the plants increase in size; that injuries and serious browsing constitute nearly all of the important damage to trees below 3.5 feet high, but that above this height most of the serious damage is due to rubbing, which becomes more acute with increase in height up to 5.5 feet.

Figure 2, which is constructed from the data in Table II, shows graphically the basis for these conclusions.

TABLE II.—*Damage by height classes.*

Height class.	Number of trees.	Character of injury.	Damage. Year. 1912	1913	1914	Average for three-year period. Total trees damaged.	Per cent of total trees in each class. Damage of all classes.	Severe damage only.[1]
			Number.	*Number.*	*Number.*	*Number.*		
Seedlings	2,153	Injured	272	152	131	185	9	21
		Severely browsed	322	352	143	272	12	
		Moderately browsed	166	212	43	140	7	
		Lightly browsed	91	121	19	77	4	
		Severely rubbed	.....	.....	.....	.....	.....	
		Moderately rubbed	.....	.....	.....	.....	.....	
		Lightly rubbed	.....	.....	.....	.....	.....	
1-foot class	3,294	Injured	385	232	203	273	8	18
		Severely browsed	365	365	229	320	10	
		Moderately browsed	553	587	301	480	14	
		Lightly browsed	293	351	119	254	8	
		Severely rubbed	.....	.....	.....	.....	.....	
		Moderately rubbed	.....	.....	.....	.....	.....	
		Lightly rubbed	.....	.....	.....	.....	.....	
2-foot class	1,468	Injured	135	69	81	95	6	15
		Severely browsed	195	75	125	132	9	
		Moderately browsed	356	212	154	241	16	
		Lightly browsed	207	159	54	140	11	
		Severely rubbed	.....	1	1	1	.....	
		Moderately rubbed	.....	1	.....	.....	.....	
		Lightly rubbed	.....	.....	.....	.....	.....	
3-foot class	1,212	Injured	55	37	32	41	3	12
		Severely browsed	104	73	96	91	8	
		Moderately browsed	238	229	156	208	17	
		Lightly browsed	165	183	84	144	12	
		Severely rubbed	2	23	26	17	1	
		Moderately rubbed	1	6	4	4	.....	
		Lightly rubbed	.....	4	.....	1	.....	
4-foot class	324	Injured	5	1	1	2	1	
		Severely browsed	11	9	11	10	3	
		Moderately browsed	35	30	29	31	10	
		Lightly browsed	89	73	42	68	21	
		Severely rubbed	3	9	40	17	5	
		Moderately rubbed	.....	7	3	3	1	
		Lightly rubbed	.....	.....	.....	.....	.....	
5-foot class	293	Injured	1	.....	.....	.....	.....	9
		Severely browsed	3	2	5	3	1	
		Moderately browsed	21	20	14	18	7	
		Lightly browsed	40	36	42	39	15	
		Severely rubbed	20	18	35	24	9	
		Moderately rubbed	9	7	6	7	3	
		Lightly rubbed	2	3	.....	2	1	
Above 5-foot class	201	Injured	1	1	.....	1	.....	6
		Severely browsed	.....	.....	.....	.....	.....	
		Moderately browsed	.....	1	1	1	.....	
		Lightly browsed	72	16	21	20	10	
		Severely rubbed	12	9	14	12	6	
		Moderately rubbed	25	20	22	22	11	
		Lightly rubbed	9	12	.....	7	3	

[1] Determined by adding per cent injured, per cent severely browsed, and per cent severely rubbed.

DAMAGE BY PERIODS.

To determine the damage caused during different periods of the grazing season, four examinations were made of all plots during the seasons of 1912 and 1913. The first examination was made at the beginning of the grazing season; the second early in July at the

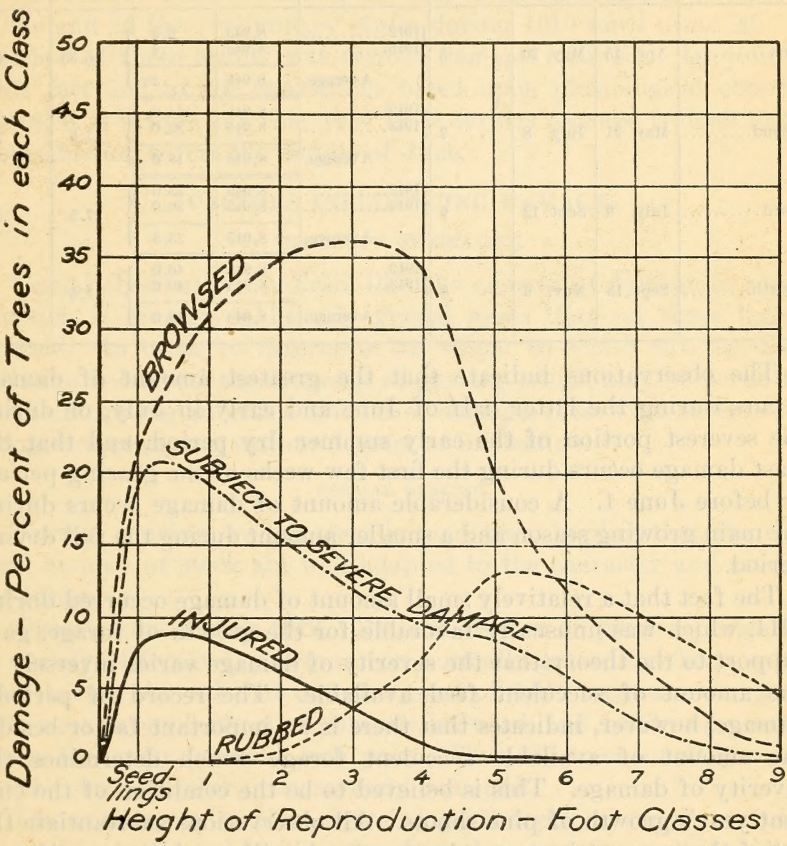

FIG. 2.—Extent of damage to reproduction of different heights.

close of the early summer drought; the third in the fore part of September, following the period of maximum plant growth; and the fourth early in November at the end of the grazing season. Results for the two years are summarized for the respective periods in Table III.

TABLE III.—*Periodic damage.*

Period.				Year.	Total trees observed.	Per cent of trees found damaged at each examination.	Average per cent of trees damaged each grazing season.	Average per cent of trees damaged per week each grazing season.
No. of period.	Beginning.	Ending.	Number of weeks.					
First	Apr. 15	May 20	5	1912	8,945	0.3	0.35	0.07
				1913	8,945	.4		
				Average.	8,945	.35		
Second	May 21	July 8	7	1912	8,945	14.0	17.6	2.5
				1913	8,945	22.0		
				Average.	8,945	18.0		
Third	July 9	Sept. 12	9	1912	8,945	35.0	17.5	1.9
				1913	8,945	36.0		
				Average.	8,945	35.5		
Fourth	Sept. 13	Nov. 6	8	1912	8,945	46.0	7.5	.9
				1913	8,945	40.0		
				Average.	8,945	43.0		

The observations indicate that the greatest amount of damage occurs during the latter half of June and early in July, or during the severest portion of the early summer dry period, and that the least damage occurs during the first few weeks of the grazing period, or before June 1. A considerable amount of damage occurs during the main growing season and a smaller amount during the fall drying period.

The fact that a relatively small amount of damage occurred during 1914, which was unusually favorable for the growth of forage, gave support to the theory that the severity of damage varies inversely as the amount of succulent feed available. The record of periodic damage, however, indicates that there is an important factor besides the amount of available succulent forage which determines the severity of damage. This is believed to be the condition of the current year's growth of pine shoots. All observations substantiate the belief that, except in unusual cases, stock will not injure coniferous shoots of a previous year's growth. It has been noted particularly that during the early summer practically no damage occurs until new shoots appear, and that damage in any year is confined largely to that year's growth. Yellow-pine vegetative buds start active growth on the Coconino Forest about May 15, and by June 20 have formed succulent shoots with well-developed needles. From that time until about the middle of August the shoots are tender and more palatable than at other periods. Thus the season of best forage growth is also the period when yellow-pine shoots are most palatable. This and the probability that during the severe spring dry period stock develop a taste for the pine shoots which continues during the early portion of the summer growing period may explain the rather severe dam-

age that continues through the season of abundant forage growth. The fact that the needles and stems become tough and therefore less palatable by September seems to account for the relatively little damage that is done during the fall period, when ordinary forage becomes dry and usually is closely grazed.

In 1912 the time of making the first count extended until early in June and in the preliminary study during 1910 until June 20. In neither of these counts was serious damage recorded. In view of this fact and of the indications based upon phenological observations, it is safe to say that very little serious damage is done to the reproduction before the middle of June.

FACTORS INFLUENCING DAMAGE.

INTENSITY OF GRAZING.

Casual observations indicate that the amount of damage to reproduction is greater on heavily grazed areas than on those lightly grazed. In order to determine the extent to which this apparent relation holds and the intensity of grazing which may be permitted without causing an undue amount of damage, plots were observed on ranges representing various degrees of utilization.

NORMAL GRAZING.

Normal grazing, as the term is used here, implies that the class and number of stock are well adapted to the character and amount of forage.

Observations during 1912, 1913, and 1914 on 92 plots, representing a variety of forage types on ranges normally grazed by sheep, cattle, and horses, showed that out of a total of 3,352 trees an average of 126 were injured, 258 were severely browsed, and 1,023 were moderately to lightly browsed each year. Thus 384 trees, or 11 per cent of the entire number, were severely damaged.

Observations on 14 plots, containing 571 trees, on ranges normally grazed by cattle and horses only, showed no trees injured during the three-year period, none severely browsed, and only 11 moderately to lightly browsed. The number of plots in this series is perhaps insufficient to form the basis of general conclusions, but extensive observations elsewhere bear out the belief that cattle and horses, under proper conditions of grazing, do a negligible amount of damage to forest reproduction.

OVERGRAZING.

By overgrazing is meant grazing by an excessive number of stock, with consequent injury to the palatable forage. Of 1,792 trees on two plots on ranges overgrazed by all classes of stock, an average of 298 were injured annually, 335 were severely browsed,

and 474 were moderately to lightly browsed. Thus 633, or 35 per cent of the total number, were subject to severe damage.

Of 522 trees on 14 plots on an overgrazed range open to cattle and horses only, an average of 11 were injured annually, 55 were severely browsed, and 194 were moderately to lightly browsed. Thus 66 trees, or 13 per cent of the total number, were subject to severe damage. This injury is not excessive in itself, but when compared with the negligible injury which cattle and horses cause on normally grazed areas, it forms an additional reason for insisting upon the protection of the range against overgrazing, especially on areas where all of the established reproduction is needed.

The general conclusions from these observations are: (1) That on ranges properly grazed by sheep as well as by cattle and horses, a very considerable amount of damage occurs, but that where only cattle and horses graze under such conditions a negligible amount of damage results; and (2) that where overgrazing occurs serious damage is caused by any class of stock.

DENSITY, AMOUNT, AND CHARACTER OF FORAGE.

DENSITY OF FORAGE.

Since the intensity of grazing has a direct relation to the severity of the injury to tree reproduction, the inference might be drawn that on a range supporting a scattered stand of forage plants the percentage of trees damaged would be materially greater than on a range where the stand of forage is good. In order to determine whether this is so, observations were made on ranges where the average density of forage plants was less than two-tenths, and on ranges where the average density was four-tenths of the ground surface. The plots were selected as representing all degrees of grazing. On 39 plots supporting a good stand of forage and 1,010 trees, 31 trees were injured, 119 were severely browsed, and 255 were moderately to lightly browsed. Thus 150, or 15 per cent of the total, were subject to severe damage. On 92 plots, containing 3,678 trees, on range poorly stocked with forage, 157 trees were found to be injured, 500 severely browsed, and 882 moderately to lightly browsed. Thus 18 per cent of the total were being severely damaged.

These comparisons indicate that under average conditions there is not a great deal of difference in the amount of damage done on ranges well stocked with forage plants and on ranges poorly stocked. In general, therefore, it may be concluded that in a given forage type, with the same amount of forage allotted each animal, the density of the forage has little relation to the amount of damage to pine reproduction.

AMOUNT OF FORAGE BY SEASONS.

The fact that a greater amount of damage occurs during the dry period of early summer, when ordinary forage is scarce, than during other periods of the grazing season suggests the probability that during a season when feed is unusually abundant the amount of damage will be relatively small. This supposition is confirmed by a comparison of the damage done in 1914 with that done in 1913.

Ordinarily not enough precipitation occurs during May and June to support the vegetative growth, and as a result not enough forage is produced to meet the needs of stock. This was the case in 1913; but in 1914 the dry period was broken in June by sufficient rainfall to revive the forage, and this was followed by abundant rainfall in July and August. Since the three months from June to August form the main growing period, 1914 was an unusually favorable year for the production of forage, and 1913 an unusually poor one. (See Table IV.)

TABLE IV.—*Precipitation during the growing periods of 1913 and 1914.*[1]

Average for yellow-pine type.	May.	June.	July.	Aug.	Sept.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1913	0.01	0.08	2.25	2.83	2.13
1914	.49	1.45	4.54	2.47	.74
Average for 11 years (1902-1912)	.77	.47	3.1	4.39	2.02

[1] The monthly rainfall is an average for the entire yellow-pine type, based upon the records at Fort Valley, Flagstaff, and Walnut Canyon.

TABLE V.—*Comparison of the serious damage caused by grazing during 1913 and 1914.*

Year.	Trees seriously damaged.	
	Number.	Per cent of total.
1913	1,417	15.8
1914	1,162	13.0

Table IV indicates that vegetation could not have made any considerable growth in 1913 before July, and the record of periodic damages shows that more than one-half of the total annual damage for that year occurred during this dry period. No record of periodic damage was kept in 1914, but a summary for the year (see Table V) reveals 13 per cent of the entire number of trees seriously damaged, as compared with 15.8 per cent for 1913. The lower per cent of damage for 1914 is believed to be due chiefly to the greater abundance of feed during that year, particularly during June and early in July.

This suggests the conservative use of forage as a means of preventing excessive injury to reproduction.

CHARACTER OF FORAGE.

Observations were made to determine the relative amounts of damage to reproduction in the principal forage types of the yellow-pine belt.

Two main classes of forage are found in the yellow-pine type of the Southwest. These are the mountain bunchgrasses (*Muhlenbergia gracilis*, *Festuca arizonica*, and *Blepharoneuron tricholepis*) and blue grama grass (*Bouteloua gracilis*), which occurs usually on the more level mesas. Both types, with variations, are prominent on the Coconino Forest. The blue grama is very palatable to all classes of stock. The bunchgrasses, though very nutritious, are not generally preferred by any class of stock because of their accumulation of coarse, dry foliage.

The general conclusions regarding the relation of the intensity of grazing to the amount of damage to tree reproduction are believed to apply in the case of the grama range. But in the case of the bunchgrass type, a serious amount of damage occurs on some portions, even though the type is not grazed closely. A study was therefore made to determine which class of stock is responsible for such damage.

Since no bunchgrass areas are grazed exclusively by sheep, it was necessary, in order to determine the damage done by this class of stock, to compare the amount of damage done on bunchgrass areas by both sheep and cattle with that on similar areas grazed by cattle only. Accordingly 72 plots were selected in the bunchgrass type grazed moderately by both classes of stock. These plots contained 2,372 trees subject to grazing. During 1912 and 1913 counts on these plots showed an average of 428 trees injured and 320 trees severely browsed, or a total of 32 per cent which, if present conditions continue, may be expected to become seriously injured. On a number of the plots practically every tree had been killed by grazing. As compared with these figures there were no injuries or severe browses on the 15 plots in this type located on areas grazed closely by cattle only. Of the total of 618 trees only 7 were even moderately browsed.

The obvious conclusion that sheep are chiefly responsible for the severe damage is substantiated by the fact that the serious damage noted was characteristically that of sheep, that is, the needles were cropped closely along the stems, instead of the end of the shoot being eaten off.

It is not assumed that the injuries on the sheep-grazed areas are representative of the bunchgrass type as a whole. All of the plots studied were located in the north half of the Forest, where the bunch-

grasses occur in much purer stand than over the remainder. In the rest of the Forest blue grama, Gambel's oak, and succulent weeds form a considerable percentage of the vegetation comprising the bunchgrass type. Extensive observations in this portion, supplemented by many others in the yellow-pine type in the Southwest, bear out the conclusion that where sheep are not forced to depend upon the rank growth of bunchgrasses for the main part of their feed, but have access to plenty of browse and palatable weeds, they will not cause such severe damage to yellow-pine reproduction in the bunchgrass type. If, however, the browse and weeds are not sufficient to supply the bulk of their feed, they are likely to cause very severe injury to young pines.

The portion of the bunchgrass type on the Coconino Forest, over which the damage is excessive, includes about one-third of the total, or 130,000 acres. A circumstance which makes the injury to reproduction here a serious matter is the fact that where the worst damage occurs reproduction is scattered, and for that reason is in special need of protection.

CLASS OF STOCK AND METHODS OF HANDLING.

CLASS OF STOCK.

It is comparatively easy to determine the amount of damage for which cattle, horses, and burros are each responsible, because frequently these classes of stock are handled in pastures where each may be observed separately. In the case of sheep, however, which are not handled in pastures on the Coconino Forest, but share the open range with other classes of stock, it is difficult to determine the proportion of the damage with which they can properly be charged. To arrive at a conclusion it was necessary to compare the amount of damage found on range occupied by both cattle and sheep with the amount of damage under similar grazing conditions on areas from which sheep are excluded and in pastures. This measure of sheep damage is believed to be fairly accurate, since there is no evidence that cattle do more damage to reproduction on a range which they share with sheep than on a range which they graze alone. Sheep injuries, furthermore, are characteristic and may be readily distinguished from those of cattle and horses.

It is believed that horses and burros may be eliminated from the classes of stock responsible for severe injuries to reproduction. The many saddle horses, in all kinds of physical condition, ridden in the yellow-pine type, have shown no disposition to eat coniferous reproduction. In a pasture 4 miles southwest of Flagstaff about 30 head

of horses were grazed from May until November, 1910. The only other stock using the pasture were from three to five head of cattle and two or three head of sheep. The number of stock was greater than the carrying capacity warranted, and in the fall all forage was cropped very closely and the horses were poor and rough. Counts made in October showed that of 365 trees only 8 trees, or 2 per cent of the total, were seriously browsed. In a grama-grass weed pasture at Fort Valley, containing approximately 360 acres, about 12 horses were kept during the grazing season of 1910. Observations on 15 plots showed practically no damage.

Burros form a very small proportion of the total number of stock on the Forest. However, the fact that they often show little discrimination in the selection of their feed raises the question of the amount of damage which they do to forest reproduction. At the Rees's sheep-headquarters camp, located in the bunchgrass type on the north slope of the San Francisco Peaks, five burros were run during the seasons of 1913 and 1914 in a pasture containing about 160 acres. Observations made in October, 1914, upon 200 trees less than 4 feet in height showed no damage whatever by grazing.

The amount of damage under different range conditions on sheep-grazed areas and on areas from which sheep are excluded has already been discussed. In order, however, to estimate the relative damage chargeable to sheep and to cattle under average conditions in the yellow-pine type, range conditions has been given a weight in per cent representing the importance of each to the whole. The percentage of severe damage attributable to cattle and to sheep has been multiplied by the number representing the importance of each range condition and an average arrived at which represents the relative amount of damage for which these two classes of stock are responsible and the total per cent of damage which each class is believed to be causing over the entire Forest. The results are given in Table VI.

TABLE VI.—*Comparison of cattle and sheep damage.*

Condition of range.	Comparative importance. Per cent of total.	Amount of serious damage (per cent of total stand).		Condition of range.	Comparative importance. Per cent of total.	Amount of serious damage (per cent of total stand).	
		Cattle.	Sheep.			Cattle.	Sheep.
Normally grazed	38	0.008	4.18	In flats	0.92	0.20	0.20
Overgrazed	6	.78	2.10	Around water and salt licks	.05	.03	.03
Poorly stocked with forage	12	.04	.31	Corrals, ranches, and bed grounds	.03	.02	.02
Well stocked with forage	28	.08	.62				
Bunchgrass	15	.001	1.50	Total	100.00	1.159	8.96

F-1 RRH

FIG. 1.—UNINJURED THRIFTY YELLOW-PINE REPRODUCTION FROM 4 INCHES TO 4 FEET TALL AND FROM 3 YEARS TO 14 YEARS OLD.

F-2 RRH

FIG. 2.—A YELLOW PINE 4½ FEET TALL, WITH LATERALS SEVERELY GRAZED BY SHEEP. LEADER OUT OF REACH OF THIS CLASS OF STOCK.

F–3 RRH

FIG. 1.—TYPICAL SHEEP DAMAGE. SHOOTS EATEN AND NEEDLES PULLED.

F–4 RRH

FIG. 2.—TYPICAL CATTLE DAMAGE. SHOOTS SEVERELY EATEN, BUT NEEDLES LEFT LARGELY INTACT.

F-5 RRH

FIG. 1.—WESTERN YELLOW-PINE SAPLINGS, 4 FEET AND 6 FEET TALL, SEVERELY INJURED BY CATTLE RUBBING.

F-6 RRH

FIG. 2.—A THRIFTY STAND OF REPRODUCTION IN A PASTURE AND A SCATTERED STAND OF BADLY INJURED REPRODUCTION ON THE OUTSIDE.

According to this table the ratio between the severe damage caused by cattle and that caused by sheep is approximately as 1 to 7.7. Striking variations from this ratio may be noted on the normally grazed areas and on the bunchgrass range. Over these portions of the type the damage caused by sheep is far out of proportion to that caused by cattle. On the other hand, in flats, around camps, and near water and salt licks the damage caused by each class of stock is about the same. On areas representative of the rest of the yellow-pine type the ratio of damage caused by cattle as compared with that caused by sheep approximates the average ratio of 1 to 7.7. This ratio is thought to be fair to the sheep. The proportion of reproduction severely damaged by both sheep and cattle is approximately 10 per cent. While this is not so high as the figure estimated for the half of the yellow-pine type under observation, which, according to Table I, amounts to 16.7 per cent, yet it is probably more nearly representative of the yellow-pine type as a whole.

The foregoing data point to the conclusion that stock do not eat yellow-pine reproduction through preference; that where the palatable forage is sufficient, reproduction will not suffer seriously from grazing; but that, on the other hand, where the palatable feed is not sufficient for the class of stock using the range, yellow-pine reproduction is likely to be seriously damaged.

METHODS OF HANDLING.

From the conclusions reached under the preceding heading it is plain that the way stock are handled on the range has a most important bearing on the amount of damage that is done to reproduction. It has been pointed out, for example, that on bunchgrass range, which, under the methods of handling stock on unfenced range, at least is poorly suited to sheep grazing, this class of stock is likely to injure one-third of the stand of reproduction, as compared with an injury of 10 per cent of the stand on range well suited for sheep grazing and that the injury on an overgrazed range varies from three times the amount of damage on a normally stocked range to total destruction of the reproduction.

Further evidence as to the relation between the handling of stock and the amount of damage to reproduction is brought out by a study of the damage on areas where stock congregate.

Rubbing by cattle.—Over the Forest, as a whole, the principal damage caused by cattle is by rubbing. This damage is serious where cattle are accustomed to congregate, principally at the edges of parks, in alluvial flats, along drainage lines, and in the vicinity of watering places, corrals, and salt licks.

Counts were made on 17 plots located in situations subject to this kind of injury. Of 165 trees above 3 feet in height, and so of a size subject to severe damage by rubbing, 36 were seriously injured. Fifteen were so badly rubbed that they would become worthless if the rubbing continued, and 2 were moderately rubbed. Thus 22 per cent of the trees subject to this class of damage had been severely injured, and 9 per cent were being subjected to severe damage. In all, a total of 31 per cent would in time be killed. This indicates a serious condition over certain parts of the yellow-pine type. The sites on which such damage is most likely to occur support the best quality of timber.

Damage along sheep driveways.—In the southern part of the Forest the only places where pine reproduction seems to be injured are around watering places, near the lower boundary of the yellow-pine type where reproduction is scattered, and along the Mud Tank sheep driveway. This driveway, with an average depth of 1 mile, extends about 30 miles through the yellow-pine type. About 75,000 sheep are driven over it each year. Besides its use as a driveway, the strip is included in sheep and cattle allotments, and would be fairly well grazed by stock throughout the season without the additional use by transient stock. The first few bands find sufficient feed, but before the total number have crossed the feed is so short that sheep are forced to eat whatever growth is available, including a great deal of yellow-pine reproduction. The damage caused in this way is so severe that the boundaries of the driveway can readily be traced by the line of severe damage. Conditions on this trail are typical of a number of trails in Arizona and New Mexico. Good management requires that this damage be reduced to the minimum.

Around watering places and ranches where stock are allowed to congregate it is very common to find a majority of the reproduction badly deformed and stunted, as a result of browsing and rubbing.

EFFECTS OF GRAZING INJURIES UPON WESTERN YELLOW-PINE REPRODUCTION.

ESTABLISHMENT OF REPRODUCTION.

INJURIOUS EFFECTS.

Abundant reproduction is often found in pastures, while just outside, with no apparent change in natural conditions, it is relatively scarce. In all such cases observed the outside range had been subject to severe grazing by all classes of stock for a number of years after the pasture had been constructed. A comparison of the ages of reproduction within and those adjacent to the pastures indicates that the effect of severe grazing outside has been not only to prevent the establishment of reproduction, but also to kill many of the trees already established at the time the fences were built. This conclu-

sion is supported by detailed observations made on small fenced areas on overgrazed ranges. One of these fenced areas, including about 2 acres, is located near the Bottomless Pits, 6 miles southeast of Flagstaff. At the time when the fence was constructed, in the spring of 1912, all reproduction in the vicinity had been badly injured by grazing for a number of years. During the three years from 1912 to 1914 the trees inside the fence were entirely protected, while those outside were subject to the same degree of grazing as formerly. A record was kept of the reproduction located within the inclosure and also of that on a check area of the same size near by. Of 57 trees within the inclosure only 5 died during the three years, whereas of the 45 trees on the check area 32 had died. Thus a loss of 9 per cent occurred among the protected trees, as compared with a loss of 71 per cent among the trees subject to continued grazing. While this contrast is unusual, it indicates the possible effects of very severe grazing.

Along most pasture fences which mark the line between good reproduction and scanty reproduction are also areas which have not been severely grazed. Where these begin the scanty reproduction ends.

It is asserted frequently that stock destroy a great many 1 and 2 year old seedlings. While this doubtless is true, it is also a fact that in inclosures entirely protected from grazing nearly all of the reproduction that germinates is killed by adverse natural agencies. Only during a series of favorable years does any considerable amount of reproduction become established. Observations in pastures and on sheep-excluded areas indicate that cattle and horses ordinarily do very little damage to reproduction of the seedling class, even though the larger trees suffer as a result of overgrazing. Though sheep probably do more or less damage to young pines during the first year, by far the greater number of such seedlings would die in any event during the following winter or spring.

At 2 years of age a seedling may be said to be well enough established to give it an even chance of survival against adverse natural agencies. For this reason the influence of grazing injuries after this period increases in importance. Table II indicates that injury to trees of the seedling class or to trees between the ages of 2 years and 6 years is more serious than in the case of larger trees. The fact that 21 per cent of trees of the seedling class are severely damaged indicates that grazing seriously handicaps young trees in becoming thoroughly established. Thus, though grazing is not a prime factor in the establishment of a seedling during its first or second year, it may seriously interfere with its growth after that age.

BENEFICIAL EFFECTS.

Probably the only important ways in which stock aid in the establishment of reproduction are by helping to plant the seeds and by reducing the fire menace.

Sheep aid very materially in covering the seeds of grasses, thus helping to insure their germination.[1] It is reasonable to suppose that they aid in planting the seed of yellow pine. However, this aid is not very important, because the important problem in establishing a stand of reproduction is not to secure germination but to resist freezing during the following winter and starvation during the long dry period of the following spring.

Grazing, by preventing the accumulation of rank growth, plays no small part in preventing severe ground fires.

HEIGHT GROWTH.

The extent to which the growth of young trees is retarded forms the most obvious index of the severity of the effects of grazing injuries. The effects upon height growth, however, indicate the immediate results of injuries and may or may not be a guide to the more permanent effects.

On Taylor's ranch, 9 miles northwest of Flagstaff, is a pasture in which the reproduction is abundant and free from injury. Just outside of the pasture damage by grazing has been very severe. Measurements of the height growth of saplings for the last five years within and outside the pasture gave the results shown in Table VII. Twenty trees form the basis for each height class.

TABLE VII.—*Comparison of height growth of trees in and outside of pasture.*

Height class.	Growth of the average tree during last 5 years.	
	In pasture.	Outside of pasture.
Feet.	*Feet.*	*Feet.*
1	1.02	0.6
2	1.45	84
3	1.97	97
4	2.53	1.26

The growth outside of the pasture is scarcely more than 50 per cent of that inside.

Measurements of 75 representative trees selected from three of the inclosures fenced in connection with this project in 1912 revealed an

[1] Journal of Agricultural Research, Department of Agriculture, Vol. III, No. 2, "Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation," by Arthur W. Sampson.

average growth of 0.7 foot for the three-year period, 1912–1914. Measurements of a similar number of trees growing in the check plots just outside these fenced areas showed an average height growth of 0.2 foot for the three-year period.

The rate of growth of 46 badly grazed saplings at Fort Valley, 9 miles northwest of Flagstaff, and 59 uninjured saplings of the same age in a pasture on Observatory Hill, just outside of Flagstaff, the two sites being very similar, are given in Table VIII.

TABLE VIII.—*Comparative growth of trees in pasture and on overgrazed range.*

Location.	Number of trees.	Average age.	Average height.	Average annual growth.
		Years.	*Feet.*	*Feet.*
In pasture	59	17.2	5.2	0.36
Overgrazed range	46	17.0	2.1	.12

The foregoing comparisons, which are believed to be representative, indicate that grazing injuries decrease the rate of growth of young trees from one-half to two-thirds.

From the standpoint of the production of a crop of timber this check in the growth of reproduction is not a serious matter, provided the trees have a chance to outgrow the injuries before their vitality is destroyed. The addition of 20 or 30 years to the period of rotation is not in itself a vital consideration in the management of yellow pine. Retarded growth is a serious matter, however, when it is considered that grazing conditions are generally stable and that where severe damage occurs the trees have no opportunity to outgrow their injuries, but are slowly killed.

FORM OF TREE.

It is generally thought that the bole of a young tree that is severely injured is likely to become crooked or forked. This belief appears to have little basis in fact. The probable cause of crooked boles in nearly all instances is that the trees have at some time been overtopped or suppressed and in that condition have grown at an angle toward the strongest light, later becoming dominant or codominant and attempting to grow upright. Forked boles serious enough to be objectionable are formed at a height above that affected by grazing. Observations of a great many young trees recovering from severe injuries revealed no deformities that promised to be at all prominent when the trees mature. Nearly all grazing injuries occur at a height of less than 4½ feet, and the trees, when protected, very quickly develop a leader which gradually outstrips all others. The laterals of

young trees made bushy by injuries contribute to the more rapid growth of the main bole.

PERMANENT EFFECTS.

It is important to know what becomes of the seriously injured saplings. If they recover and become normal trees, then the ultimate effects of such damage are unimportant. But if a considerable portion of them die, and if others remain dwarfs or develop into deformed trees, then the need for applying protective measures is apparent. Owing to the slow growth of yellow pine, effects of grazing injuries upon the later development of reproduction requires a good many years to determine. Observations so far made, however, indicate clearly the effects that may be expected where injured reproduction is protected and where it remains subjected to continued severe grazing.

Observations of a great many trees formerly injured but later protected from grazing indicate conclusively that young injured pines have remarkable recuperative powers. Even though they have been eaten off repeatedly for as long as 10 years, a few years' protection will enable them to recover. Unless the injuries are particularly severe, the subsequent growth is as rapid as in the case of younger uninjured trees of the same height. Ordinarily, trees subjected to repeated grazing develop many laterals capable of supporting vigorous height growth at the first opportunity. When protection is afforded to such trees, the ultimate effects of the injuries appear to be simply the retardation of growth equivalent to the period of serious injury plus 5 to 10 years required for the plant to regain its normal vitality and to develop a well-defined leader. If, however, the young trees are defoliated, as is characteristic of severe sheep injuries, recuperation is necessarily very slow.

The ability of injured trees to recuperate if protected is well illustrated at the Fort Valley Ranger Station pasture. Previous to three years before the observations were made, the pasture had been greatly overstocked with cattle during certain portions of the year, but since that time it has been grazed only moderately. Reproduction is abundant, but during the period of overgrazing the saplings were severely damaged. Practically no damage was done in the three years preceding the observations. A comparison of the last three years' growth of saplings in the pasture previously injured, but showing no damage during this period, and of the growth during the same period of injured saplings just outside the pasture where severe grazing conditions prevailed, gave the results presented in Table IX. Twenty trees in each of four height classes were examined.

TABLE IX.—*Comparative growth of protected and unprotected saplings.*

Height classes.	Average growth during 3 years.	
	In pastures.	Outside of pastures.
Feet.	*Feet.*	*Feet.*
1	0.8	0.2
2	1.1	.3
3	1.2	.4
4	1.4	.4
Average	1.1	.32

The results show that the growth of the protected saplings is more than three times as rapid as that of the unprotected ones and indicate a marked ability of young pines when protected to recover from injuries. This conclusion is substantiated by the results of measurements of trees previously injured within the fenced plots and of trees outside subject to continued injury (p. 18). As stated in that case, the ratio of growth between protected and unprotected trees was as 7 to 2.

Even though protection against severe grazing may enable seriously injured saplings to recover, such protection may not be advisable unless the loss of young trees on unprotected areas is excessive. Reference to Table I shows that an average of only 0.9 per cent of the total number of trees were found dead during the three years covered by the study. While this loss probably represents the average mortality from grazing over the Forest as a whole, yet it does not adequately express the seriousness of the losses in certain important parts of the Forest. Areas exist where more than 50 per cent of the total number of young pines have been killed. Such areas include many sections of the bunchgrass type south and west of Lake Mary, the edges of parks, bedgrounds, driveways, the vicinity of headquarter ranches and water holes, and range areas that have been overgrazed for a long period.

It is estimated from a comparison of the age and height of 265 trees that a yellow pine will ordinarily, if uninjured, reach a height of 4.5 feet—above which it can withstand severe grazing injuries—when 15 years old, but that if it is subject to repeated grazing injuries it may require 35 years to reach this height. If it may be assumed that under average conditions which prevail over the Forest it requires 17 years for reproduction to reach a height of 4.5 feet, and that, as shown in Table I, 0.9 per cent of all trees observed die annually as a result of grazing injuries, it is safe to conclude that the loss of trees during the period when they are subject to severe grazing is approximately 15 per cent of the stand, or nearly as many as are

seriously damaged each year in the north half of the yellow-pine type.

This poor showing of the injured trees would not be such a serious matter were it not for the fact that even though an injured tree does not die immediately, the needles, after repeated grazing, become dwarfed and turn yellowish, and the whole plant becomes stunted. If injury is continued the vitality is so weakened that a severe season or an attack by natural enemies is very likely to kill the tree. It is not uncommon to find saplings so impoverished by continued defoliation that they can readily be pulled out of the ground by hand.

The destruction of young trees is not such a serious matter where more reproduction has become established than is necessary to insure a complete regeneration of the stand. But where the reproduction is more or less scattered, the loss of a considerable percentage of young trees becomes decidedly important.

SUSCEPTIBILITY TO FUNGOUS AND INSECT ATTACKS.

It is commonly supposed that young trees injured by grazing are more susceptible to attack by fungi and by insects than are uninjured trees. The extent to which this danger actually exists, and under what circumstances, is a subject which deserves careful consideration.

Dr. W. H. Long, forest pathologist for Arizona and New Mexico, who has made a special study of fungi attacking western yellow pine, has expressed the opinion that—

> The fungi and diseases known at the present time to cause serious damage to yellow pine in the Southwest normally do not enter trees through ordinary injuries caused by grazing. The spores of certain species of rust (*Peridermium* spp.) may enter through wounds in the living bark of pines, and it would be entirely possible for such spores to enter through wounds caused by grazing. However, the total damage due to such a rust entering through grazing wounds and finally girdling the trunks of yellow pine is probably very small.
>
> No heart-rotting fungus is known which is apt to start growth through grazing wounds other than in cases where the bark is removed or where the heartwood and sapwood are exposed by breaking and twisting. Since injuries of this character form a very small part of the total amount of damage, the danger of fungus attack due to them does not require serious consideration. Injuries that favor this kind of rot are caused by lightning, fire, deep blazes, etc.
>
> It might be presumed that mistletoe (*Razoumofskya* spp.) would be liable to attack grazing wounds, but a knowledge of the circumstances under which this parasite attacks tissue leads to the conclusion that this danger is relatively unimportant, for while it is true that mistletoe berries start growth where new tissue is exposed, such as on the calloused edges of blazes, and while the wounds to tender shoots such as are caused by grazing might afford favorable conditions for germination of these berries, the conditions are probably no more favorable than they are on the tips of uninjured stems.

Certain needle diseases exclusive of rusts are believed to attack dwarfed and unhealthy needles more readily than vigorous needles. Since the effect of moderate grazing wounds is to stimulate the growth of plant tissue, these needle diseases are not apt to secure a foothold more readily because of them. However, when persistent and severe wounds reduce the vitality of the trees until the needles reflect the weakened condition, certain needle diseases are apt to find favorable hosts. The total amount of damage caused by needle diseases or the increase in this character of damage which may be attributed to grazing is not known, although it is believed to be relatively unimportant.

During the last two years studies of the extent of damage by insects on the Forests of Arizona and New Mexico have been made a special study by A. J. Jaenicke, forest assistant in charge of insect studies. Mr. Jaenicke has expressed the opinion that grazing injuries are not responsible for a serious amount of insect damage to western yellow-pine reproduction. He states that—

Western yellow-pine reproduction in Arizona and New Mexico suffers particularly from the following insects:

1. Tip moths of the genus *Retinia*. These kill the terminal shoots of the reproduction, causing it finally to assume a bushy form, but rarely kill it.

2. Engraver beetles of the genus *Ips*, particularly *Ips confusus* Leo. These insects are responsible for the death of considerable reproduction in various parts of the district, particularly on cutting areas.

3. Small scolytid beetles, which work in the thinner bark of the young trees and occasionally cause their death.

4. Flat-headed borer of the family of *Buprestidæ*. These were found doing serious damage on only one Forest in the district.

During the past field season careful attention was given the relation of grazing injuries to attacks by the above-named insects. It was found that only in localities where serious overgrazing has taken place for a number of years is there ever any material increase in insect damage.

The tip moth kills the terminal shoots of healthy and unhealthy reproduction with equal ease. Grazing injuries, therefore, are an unimportant factor in infestations by this insect.

Wherever the vitality and health of reproduction has been seriously lowered by overgrazing or any other cause, particularly on areas recently cut over, engraver beetles may become responsible for the rapid death of the injured seedlings. The same is true of attacks by various small scolytids. Both the engraver beetles and small scolytids breed in slash, and so it is on the areas where there has been recent cutting that reproduction injured by grazing suffers most from these insects. It is not believed that attacks by flat-headed borers are increased by grazing injuries.

The minor injuries caused by regulated grazing, therefore, are of little importance in augmenting insect attack. Even serious injuries are rarely responsible for insect damage of any consequence, except on recently cut-over areas.

SUMMARY.

(1) Of 8,945 trees of a size subject to grazing, observed over a period of three years, 1,493, or 16.7 per cent, were severely damaged each year and 1,442, or 16.1 per cent, were moderately damaged.

(2) The most injured are the seedlings, 21 per cent of which are seriously damaged. The damage gradually decreases with an increase in the size of the trees. Trees above 4.5 feet in height are free from severe injuries from browsing, but those between 3 feet and 6 feet in height are likely to be rubbed severely.

(3) The greatest amount of damage occurs during the latter half of June and the first part of July, or when the effects of the spring dry period are most pronounced. The least damage occurs during the first few weeks of the growing period, or before June 15. A very considerable amount of damage is done during the main growing season and during the fall drying period.

(4) Under normal conditions of grazing cattle and horses, and incidentally burros, do an inconsiderable amount of damage to reproduction. Sheep under the same conditions may be responsible for severe injury to 11 per cent of the total stand.

On overgrazed areas all classes of stock are apt to damage small trees severely. Cattle and horses may damage about 10 per cent of all reproduction. Where sheep are grazed along with them, however, at least 35 per cent of the total stand may be severely damaged.

Cattle and sheep are responsible for practically all of the grazing damage to yellow pine on the Coconino forest. Ordinarily sheep cause about seven and a half times as much damage as cattle.

(5) The density of forage does not affect the amount of damage that may be caused on a given area.

(6) The suitability of the forage to the class of stock using a range has an important influence upon the amount of damage to timber reproduction. Because of the suitability of the pure bunchgrass type to sheep grazing, the reproduction over approximately one-third of the bunchgrass type on the Coconino Forest, or over 130,000 acres, is being seriously injured.

(7) The amount of palatable feed available during the grazing season, and especially during June and July, has an important bearing upon the amount of damage that grazing will cause to reproduction. During a favorable year the damage may be 18 per cent less than during a subnormal year.

(8) The manner in which stock is handled has much to do with the severity of grazing damage. Cattle are likely to injure 22 per cent of the trees between 3 feet and 6 feet in height that grow on areas where they are accustomed to congregate. Sheep severely injure reproduction along driveways and on bed grounds.

(9) Grazing is believed to have a largely neutral effect upon the germination and early establishment of reproduction, but to have an important effect in reducing the destruction of reproduction by fire.

(10) The effect of grazing upon the height growth of reproduction is marked. Severely injured trees grow only from one-half to one-third as fast as uninjured trees.

(11) Grazing injuries are not responsible for the common deformities of mature trees.

(12) The permanent effects of grazing injuries upon the development of the trees damaged are not serious, provided the damaged trees have a chance to recuperate. If grazing is unrestricted, about 15 per cent of the total stand is likely to be killed during the period required for reproduction to become established.

(13) Reproduction that has been impoverished greatly by grazing is more likely to be attacked by some fungi and insects than uninjured and vigorous reproduction. However, the ordinary grazing injuries are not believed to increase seriously the danger of such attacks.

APPLICATION OF RESULTS TO RANGE MANAGEMENT IN THE SOUTHWEST.

The conclusions arrived at in this study are believed to be applicable over the entire yellow-pine type of the Southwest. Since forage composition, class of stock using a range, intensity of grazing, and methods of handling stock vary on different Forests, it is not advisable to attempt to prescribe specific suggestions for certain areas, but rather to prescribe definite remedies for certain conditions.

Under present conditions all reproduction should be protected against severe damage by grazing. Where immediate cutting of the mature stand is contemplated, the reason for protection is obvious, since the prime purpose should be to insure a stand of reproduction. Where reproduction on an area not to be cut over in the near future is being injured, protection is needed to assist nature in maintaining a forest cover. Reproduction generally occurs naturally in openings made by the death of mature trees. Unless this reproduction is protected, the gaps will tend to increase and the regeneration of the forest be made constantly more difficult. Moreover, under the most favorable conditions it is only through the combination of a good seed year with two or more good growing years following that any considerable amount of reproduction becomes established. Such a combination is so rare that it is not safe to depend upon it.

The grazing of stock on National Forests must be so regulated that the number of stock shall not decrease, but, if possible, shall increase. Under proper grazing management reproduction does not suffer an unwarranted amount of damage; in fact, the advantages of conservative grazing in reducing the loss of reproduction by fire probably offset the injury from stock. The application of conservative grazing throughout the western yellow-pine type, then, is the basis for the protective recommendations which follow.

Since overgrazing is the cause of the most severe grazing damage, it should be avoided by all means. An overgrazed condition may exist even though the general appearance of the range does not indicate it, as, for instance, on a bunchgrass range allotted to sheep. The principal grasses may be largely uneaten, while sheep feed, consisting of palatable weeds and grasses, and, too often, of yellow-pine reproduction, may be largely destroyed. Overgrazing may result from allotting too many stock to a range, or from poor distribution of a proper number of stock due to lack of sufficient well-located watering places, poor salting arrangements, or, in the case of sheep, to poor herding. In any case the cause should be determined and removed.

Sheep should not be depended upon primarily to utilize the bunchgrass range. This type should be utilized chiefly by cattle and horses, held in pastures if possible. On this type, wherever the bunchgrass species occur in nearly pure stand during early spring, sheep should be run in May and the fore part of June while the grasses are tender and most palatable. Where the succulent weeds and browse species occur in mixture with the bunchgrasses, sheep may be grazed season long together with cattle and horses.

Sheep should be excluded from cutting areas on which they are causing severe damage until reproduction is well established, usually for a period of from 15 to 20 years. They should be excluded also for a period of from two to five years from cutting areas where the stand of reproduction is deficient but has been supplemented by an abundant crop of seedlings which, having survived the first winter and spring, promise to become established, even though injury to the reproduction already established is not severe.

All stock should be worked and handled as little as possible around watering places, salting grounds, and headquarter ranches. Sheep should be bedded as seldom as possible on any one bed ground, preferably for one night only.

It is very difficult to avoid the damage caused by cattle rubbing. In exceptional cases, where complete reproduction is desired within a short period, as on a cutting area, flats might be fenced and cattle excluded from them during the fly season. However, if overgrazing and excessive handling are avoided, it is believed that the damage caused by cattle will not be excessive.

One of the most serious menaces to reproduction as well as to forage occurs on stock driveways. Even at best, an excessive number of stock must use these strips of range and injury can not be avoided. However, all practicable means should be used to conserve the stand of forage and by furnishing sufficient feed for the stock using the driveways to reduce the injury to reproduction to a minimum. In order to accomplish this, it is recommended that driveways be used

as little as possible; that, wherever practicable, they be closed to grazing except by passing stock; that a sufficient number be established to prevent overgrazing; and that water be furnished in abundance at proper intervals along them.

Every effort should be made to protect yellow-pine reproduction in the "twilight" zone between the yellow-pine type and the juniper-pinion type. Conditions here are unusually unfavorable for yellow-pine reproduction, and such seedlings as become established should by all means be protected against grazing.

Stock, especially sheep, should not be held in the yellow-pine type during the winter, when they would be forced to eat reproduction.

Advantage should be taken of grazing as a means of fire control by securing proper utilization of all range where at present an accumulation of inflammable unused feed occurs each year. Such areas are common on the bunchgrass type and on other types of range far removed from water or located on rough ridges and slopes.

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Improvement and Management of Native Pastures in the West. (Separate No. 678 from Yearbook, 1915.)

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